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Integrated component-based computer design modeling system : the implications of the representation of control parameters on the design process

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Integrated Component-based Computer Design Modeling System

The Implications of the Representation of Control Parameters on the Design Process

by

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ABSTRACT

Integrated Component-based Computer Design Modeling System ;
The Implications of the Representation of Control
Parameters on the Design Process

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The design process is dependent on a clear order of integrating and managing all of the control parameters that impact on a building's design. All component elements of a building must be defined by their: Physical and functional relations; Quantitative and calculable properties; Component and/or system functions. This requires a means of representation to depict a model of a building that can be viewed and interpreted by a variety of interested parties. These parties need different types of representation to address their individual control parameters, as each component instance has specific implications on all of the control parameters.

Representations are prepared for periodic design review either manually through hand-drawn graphics and hand-crafted models; or with the aid of computer aided design programs. Computer programs can profoundly increase the speed and accuracy of the process, as well as provide a

level of integration, graphic representation and simulation, untenable through a manual process.

By maintaining a single control model in an Integrated Component-based Computer Design Modeling System (ICCDMS), interested parties could access the design model at any point during the process. Each party could either: 1. Analyze individual components, or constraints of the model, for interferences against parameters within that party's control; or 2. Explore design alternatives to modify the model, and verify the integration of the components or functions, within the design model, as allowable in relation to other control parameters.

APPROVAL PAGE

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Dedicated to anyone who has tried to organize all of those things that go on in a building.

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The author also appreciates the interest of several industry sources for their interest in the development of the project, especially the Intergraph Corporation of Huntsville, AL. for long discussions on the currently available products that are working toward a system of integration similar to the author's concept.

And finally, a thank you to his wife, Susan, his employers and friends for helping him get through this project without losing touch with the rest of reality.

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PREFACE

This thesis anticipates development of a technological means of representation and information organization beyond the capacity of current computer systems but refers to computers as an understandable analogy. Current means of representation are typically limited by 2-D imaging or such 3-D imaging as perspectives, isometrics, or construction of scale models. While such images may serve to help analyze and understand the relationships and massing of spaces, the hidden information implied by these images is left to interpretation, with a necessary abstraction of the objective qualities of the component materials and their relationships limited to verbal or mathematical symbols.

The various means of graphic representation, and the implications of their use, through history, in current use, and recently conceived (if not yet developed), have been consciously omitted from this paper to allow the author to focus on the potentials of a means of integrating all of the components of a design and the control parameters placed on them. Control parameters can be defined as the various properties, constraints, and implications that are affected by, or have an effect on, the use, placement, and inclusion of any and all of the component elements that make up a building through its design. These component elements have mass, structural and functional characteristics, implications on the definition of space, color, relative translucency or opacity, acoustic properties, etc.

The focus of the thesis might be read as a sort of "science fiction", an analysis of the mental processes from the author's perspective discussing a method that might serve as a tool to assist the designer by analyzing the more mundane aspects or "control parameters" of the design process, allowing the designer to focus his attention on aesthetic and functional issues of the design through basic graphical and subjective means of representation.

Such a new means of representation would require an extremely large memory base and reference system of data (beyond the capacity of even the latest Cray supercomputers), and an ability to readily translate the minutia of objective details to and from a graphic representation. The hidden agenda of component elements of a design would need to be reduced to a fractal or molecular level, to fully integrate the various physical, biological, chemical, mathematical, mechanical, dimensional and other aspects of components and their relationships to operate at a usable, functional level. The system proposed in this paper seeks to outline these necessary and fundamental aspects of design. This system will provide for a means of design management that will at once allow for a spontaneous graphic representation, and a complete and fully accessible database of all of the involved components and their relevant characteristics for analysis and confirmation with design standards.

The integration of these components can be analyzed in terms of their relationships one to another, as well as within a hierarchy of component types. Some components may consist of many lower order components, while at the same time comprising a lower order instance of a higher order component system, i.e. a door is a component consisting of many lower order components including a frame, a movable panel, hinges or rollers, a handle, a latching mechanism, etc. As part of higher order systems, the door is a part of a wall, which forms part of an enclosure, which is a part of a system of enclosures, which comprise a building, which can be part of a group of buildings, etc.

The human mind establishes, recognizes, and makes full conscious use of these relationships easily, even unconsciously, without hesitation or even much confusion, after only just a few years of experience and awareness as part of a living, human being. However, these relationships tend to get lost, in confusing and variable layers of interpretation, when the designer attempts to represent those same relationships using even the most basic and standard means of graphic symbolism.

The ICCDMS described in this thesis attempts to strip away these layers of interpretation. By proposing a method for representing the design of buildings in a manner so basic and fundamental that a "computer" can be used to store and represent a model of the building, in much the same way the human mind stores and represents images, and the cognitive understandings of these images, for quick and easy translation to a representation to illustrate the ideas of the architect in a simulated image of the building for a viewer's understanding. It also attempts to provide a means of integrating each of the special and unique understandings of the physical assemblies of components that is typically held by only the few, and highly trained, professionals who are involved during a design process. The system provides a means to accumulate all of the special training, understanding, and skills of these many design professionals within a single control system, a kind of "Super-Architect". This system may allow the architect to have access, continuously and spontaneously, to the many design professionals he must typically consult with, and integrate the work of, individually and separately. The hope is to give the architect more immediate control over all of the various components and constraints that comprise the finished product of his imagination. This method should not be presumed to make the architect any more, or less, skilled at the nuances of his profession, but only as a tool, a means to allow the architect more immediate and thorough control over the design process, by accessing as much relevant and involved information as possible.

It is further to be understood that such a system is something not even close to fully realizable, although many of the separate and individual concepts are currently practiced with the use of computers and specialized computer programs. Computer databases, graphics programs, analysis programs, etc. are currently in wide use by design professionals. However, there is not, as yet, a method or means available to provide for the immediate and spontaneous integration of all of these systems. To this regard, this thesis can be viewed, in a sense, as science-fiction, acknowledging current technology, but hopefully anticipating the advances of future technologies. The author acknowledges the power and potential of current computer systems, but after some years of practice using traditional graphic methods, and recent use of computerized methods, still regards the available computer programs and systems as primitive, when compared to the natural power and speed of the human mind. The computer cannot yet replicate the abilities of the mind, but can only serve as an aid to the expression of the mind's imaginings; as a powerful and highly accurate extension of the architect's skills.

The mind can make many complex connections between seemingly unrelated concepts, and establish relationships among components and spaces through its myriad of parallel and necessarily integrated neural processes. The state of current computer technology is limited to singular or limited parallel tracks of analysis. The latest advances by Cray and the Japanese computer consortium boast of hoping to achieve 16 parallel processors in a single computer by 1995. No one knows yet how many different processes, or even how the mind does process information at any given time. The mind can also allow for ambiguous or multiple variations of component instances by realizing the limitations of its decisive processes until gaining enough further refinement of separate, but related, instances of other components or parameters. A computer database, on the other hand, must be fed relatively specific and limiting information at early stages of the design process, and be manually updated during the process, to allow for any further integration in later stages of the design.

Ideally, the ICCDMS would be linked and addressable in a manner as direct as the visualization process of the designer. By working with a stylus on a pad and sketching, erasing, and overlaying new levels of information, the design process with the ICCDMS could be accommodated to match the fluidity of sketching on tracing paper. Voice commands could be used to address the system to identify and define component elements indicated with a pointer. Dimensions and other statistics could be entered and modified through voice commands as well. The future might even hold techniques and technologies that could allow for direct electrical connections to neural impulses, providing graphic images directly from the designers mental visualizations. Most of these ideas are speculative at this point, of course, but the author feels the need to address the possibility of these issues in order to help propagate the research necessary to make them realizable, even if far into the future. Many the issues addressed in this thesis treat these abstract ideas as certain eventualities, such that the distinction between current, actual systems, and future, potential systems are described in the same tense, as they are currently mentally conceivable, and indeed mirror the perceived workings of the mind during the author's experience of the design process.

The ICCDMS will depend on a ready and quick graphic translation of any databased information that is entered by the architect. By working in a visual and verbal mode, of subjective and qualitative decision making throughout the design process, the architect could progress with the development of a building's design by allowing, or relying on, the ICCDMS to translate the visual or verbal input, to and from a database. This database will contain all of the necessary facts and objective informational data "hidden" in the component elements and systems of the building. The power of computer graphics systems will allow the architect to represent the parts, or the whole of the building, from any point, at any angle or to any view, as either solids or transparent elements. Each component element, component system, and the relationships of these components will be illustrated quickly and accurately, while simultaneously assured of being effectively and properly integrated as a part of the design as a whole.

CHAPTER 1

INTRODUCTION

1.1 The Design Process

This study will first characterize the conceptual patterns of the design process as they apply to any of the various methods architects use to proceed with the development of a buildings design. The progression of these patterns moves from the very abstract and highly variable genesis of the idea, through to higher levels of refinement and tighter adherence to the limits of various and distinct control parameters. Each of the methods of representation offers implicit characteristics of achievable refinement. These levels of representation refinement equate to the various stages of design review. Adherence to, and understanding of, the issues of control parameters are addressed at each increased level of the design review process.

The design review process will be examined as it relates to the level of accuracy depicted about the review model. The capacity of any method of representation to provide adequate information, for analysis of any one of the control parameters, will be discussed. Each method of representation will be reviewed as to its capacity to provide enough information for analysis at a variety of levels, from abstraction through definition. The various methods will be reviewed for their ability to move across various levels of definition, as well as allow simultaneous analysis of various control parameters.

The diagram below graphically illustrates the process and refinement of the design process across several review levels.

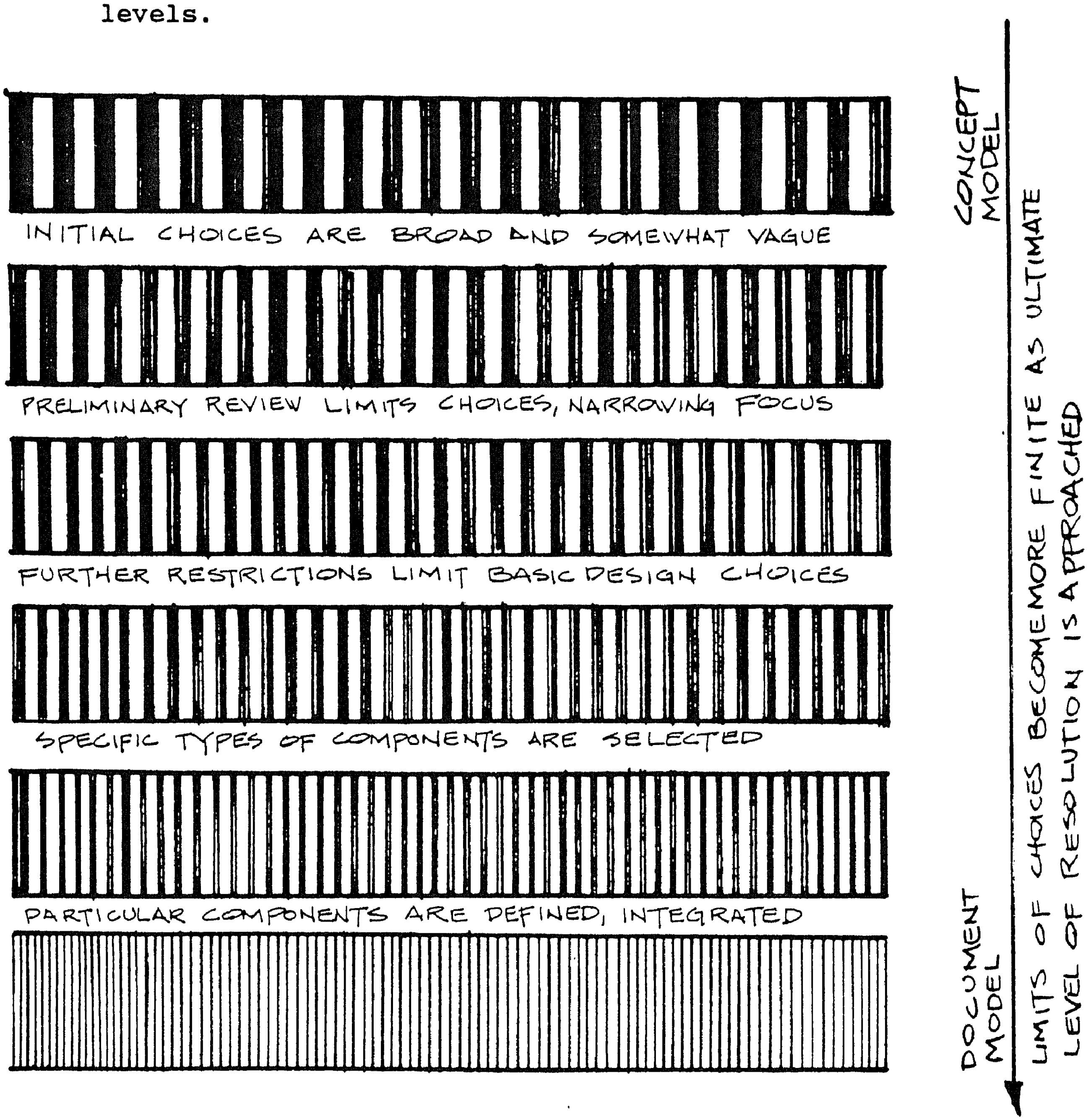


Figure 1.1: The design process

1.2 Representation Methods

From the historical and elementary methods of pencil drawings, sketches, pen and ink drawings and building of scale models out of paper, clay, cardboard and wood architects now turn to a variety of computer aided programs to can emulate the historic methods. These include simple two-dimensional line drafting systems, three-dimensional line or "wireframe" drafting systems and three-dimensional wireframe modeling programs. Some of these include or can be enhanced by shading techniques to render more real appearing entities. More recently solid modeling programs, which treat the creations from the outset as "solid entities", enabling users to manipulate them as 3-D objects so that they can be modeled in a manner similar to operations performed in real world conditions. New theories continue to emerge concerning the use of component based systems. These treat the design process with the aid of computers as simulations of actual constructions of the various component elements that go into a real building.

1.3 Control Parameters

The various control parameters that affect the end product are herein analyzed. These are illustrated in the form of flow charts that illustrate the levels of decisions within each parameter from the abstract through to the finite. The various decisions within each parameter that effect other parameters will be discussed.

Within the practice of architecture, the architects duties and responsibilities are quite varied and supposedly all-encompassing. However, in the process of design, many of the various rules, regulations, standards and public issues are typically ignored, deferred, or otherwise put off. The intent is to "let the experts deal with it later". The architect is usually more interested in producing an idealized vision of the product that will be used to sell the project to the client, building officials, zoning officials, and whoever else may be concerned at the contextual or aesthetic level. In the interest of expedition, the architect will often omit or avoid critical decisions and overlook necessary revisions that will ultimately have major implications on the final design resolution.

1.4 Integrating Control Parameters

To limit the tendency for such implications to be discovered too late as "unforeseen circumstances," the capabilities and influences of an interactive design and analysis process become more apparent. The architect using an ICCDMS could proceed along a variety of choice paths, assured that most of the necessary decisions have been addressed during the input process. This would allow the design to be more fully explored and developed at an earlier stage, and give the designer a better means to address the details, without forgetting how those details relate to the "Big Picture".

The product that results from the design process is completely dependent on the designers ability to convey the full intent of his design. This design intent must be illustrated through an adequate and accurate model. The model must illustrate the concept and appearance of the design for interpretation by the client. Each review model will be analyzed for its ability to meet the needs and aspirations of the client, and also analyzed by the various trades and engineers to qualify the integrity and ability of the design. The design must be verified as performing to the standards and requirements necessary within each control parameter.

Control parameters currently must be considered, resolved and analyzed independently and manually by the architect or his team of designers, draftsmen, engineers, managers and contractors. There is a clear need to ensure that the various views and details of any given object or space, within the overall model, must <u>each</u> provide an accurate view of the <u>same</u> objects and spaces. This accuracy relies on the careful calculation and manipulation of the design model (whether drafted, physically modeled, or computer generated) to guarantee a cross-referencing consistency. Sections, plans, elevations, and 3-D views must all agree.

Independent methods of study and analysis, for individual control parameters, maintain an inherent time lag and communications gap. These lags and gaps are due to the tendency of each control parameter designer to produce his own set of record documents. Each set of documents focuses on a separate control parameter. This separation of information leaves each designer unaware of whatever simultaneous changes may be occurring through the efforts of the designers of other control parameters. The lags and gaps are further aggravated by the dependency on control documents that are released only periodically, and which may not have been updated to reflect all of the ensuing changes to date. The opportunity to create incompatible situations and interfering conditions during the process is high. Difficult conditions tend to be overlooked until the process is nearly complete and ironically, more difficult to resolve properly. The tendency to overlook these interference conditions results in many compromises at the end of a process, in order to "just get things finished."

The architect must manage each of the control parameters' constraints on the design throughout the process. His ability to keep track of everything, and to communicate the changes to the model, to all of the various interests on a constant basis, is critical. The highly complex levels of interrelated systems, that are involved in the design process, leave manual methods full of opportunities to miss or overlook some phases of review during the design process.

In order to accomplish or perform such a highly integrated level of design, all of the component information used to create the system model should conform to consistent and logically deductive standards. The component elements of a building, and even the building itself, can be seen as instances of component products, or instances of product systems composed of a variety of subset component products.

1.5 ICCDMS-Integrated Component-based Computer Design Modeling System

An Integrated Component-based Computer Design Modeling System (ICCDMS) for designing, managing, analyzing, updating and verifying all of the component characteristics and constraints of a building can be extremely valuable.

Several design control parameters act upon the design process simultaneously, applying constraints to component input or definition. Most control parameters of a design could be run at default values, to free the architect to concentrate on more abstract distinctions. Attempts to enter information that does not meet minimum standards, according to applicable codes or requirements; or creates interference conditions; should be updated to meet minimum default values. The architect is required to make a choice regarding the correct value for the inputted information.

Relying on typical default values or allowances within ambiguous limits, the architect can proceed by selecting or modifying components from type-sets of allowable options. The architect can continue to enter information along whatever line of thinking he chooses, while the design system would prevent any interference conditions, or inadequate systems; requiring modification of components, before allowing version updates to the control model. By allowing any interested parties to work with the latest set of information as a transparent model, any modification to the design model can be applied and tested on a safe version of the model. This will prevent interference with the control model until compliance and correctness have been verified. To maintain a steady work flow and provide a method of version control, this verification interval should be at a consistent time during the design operation process. Many database management systems call for this verification at the end of any work session as a version update. (Zdonik, 1990)

1.6 Conceptual Basis for ICCDMS

Analogous to such a system of standards and rules would be the writer's use of the Dictionary, Thesaurus and Strunk and White's Rules of Grammar as well as reference to any previously published works. Although strict use of such rules might seem to limit the possibilities of the writer, they have been used quite effectively and to extremely different ends by writers as diverse as Hemingway or King, Vonnegut or Le Carre. Each writer conformed to the rules with varying degrees of adherence and interpretation, within limits of their chosen style, and managed to produce widely accepted, and highly different works.

The goal of this thesis is to provide the outline of a similar set of rules and constraints for an integrated computer design modeling system. The design system should manage and integrate all of the control parameters affecting the design process of a building. The design system should be able to illustrate the design model contemporaneously, providing a "freeze-frame" capture of the design process results to date. By observing and studying the model of the design intent, as a complete system throughout the design process, the opportunity to guide the integration of control parameters yields a much higher chance of "Getting it right."

If the visual and physical properties of components, constraints, and relationships between component entities can be translated to and from mathematical and semantic formulae, they can then be interpreted and analyzed by the computer. By thinking of the design process as a more integrated system, and by working interactively among all the control parameters through a single control model, interference conditions and incompatible situations can be considerably reduced, if not eliminated.

If we view the overall design process abstractly, where each set of control parameters is derived from the same conceptual model, and the organization of the subsets of each is broken down along similar patterns of more finite resolution, a diagram similar to a Mandelbrot diagram would emerge.

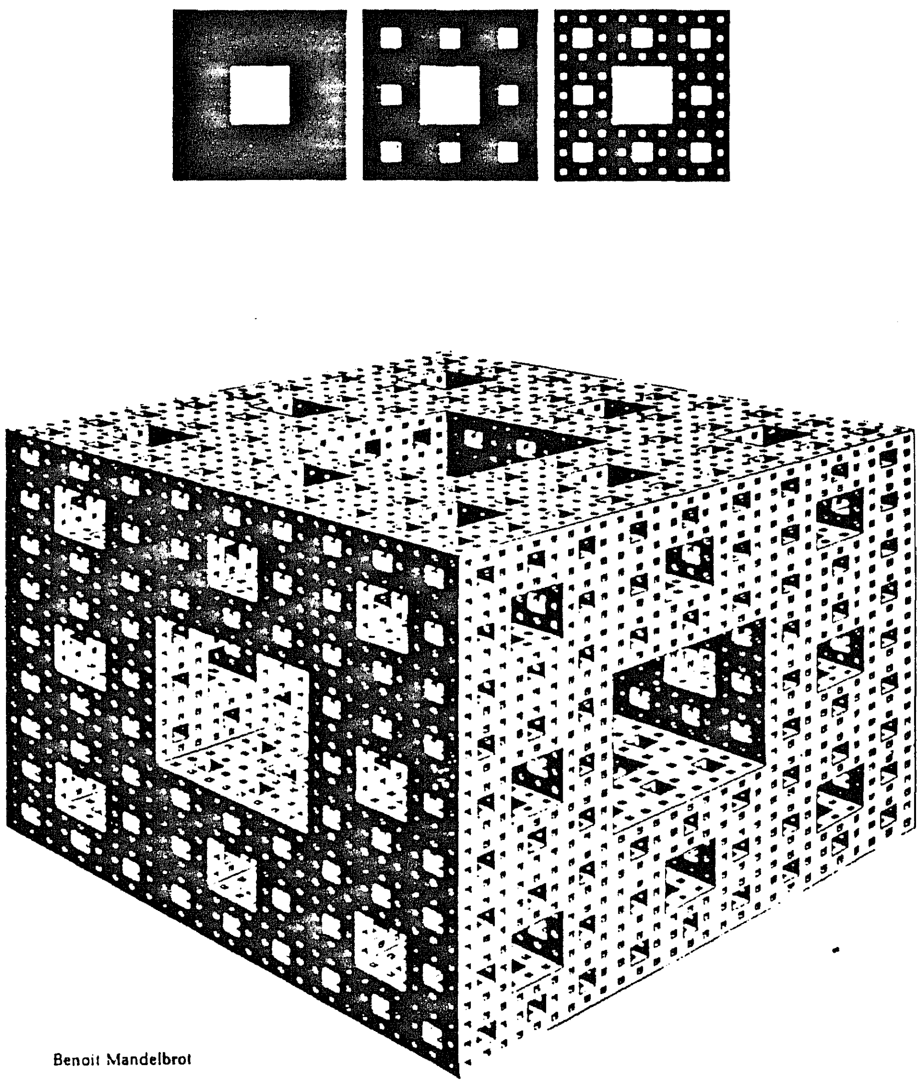
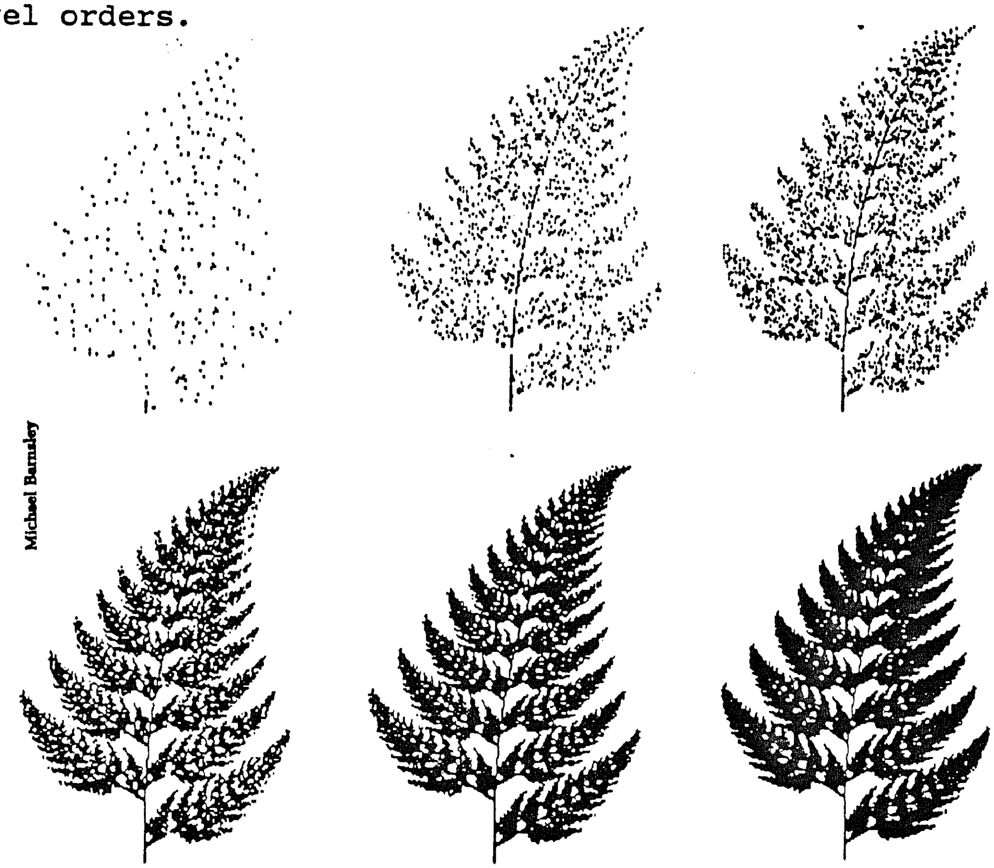


Figure 1.2: Mandelbrot diagram (Chaos)

Each level of refinement, on each branch of control parameters, tends to follow a path of definition that must emerge only as a subset of a higher level decision.

By creating what could be described as an "Infinite Tree," diagramming all the various control parameters as emerging from a single control model, we can visualize the necessary cross-referencing among each of the various branches and the clear structural dependency on higher level orders.



THE CHAOS GAME. Each new point falls randomly, but gradually the image of a fern emerges. All the necessary information is encoded in a few simple rules.

Figure 1.3: Infinite tree of control parameters

Rather than assuming that the line of each choice path move only linearly and only in one direction, we can make choices along any of the paths, moving out and back indefinitely until an optimal solution is reached.

To understand the complex and sporadic nature of the decision making process that overlies this infinite tree of parameters and their resolutions, we can visualize further the presence of a loop of inquiries into each of the parameters, each decision building on the last and carrying through to the next. For this analogy, the diagrams of Lorenz attractors are useful.

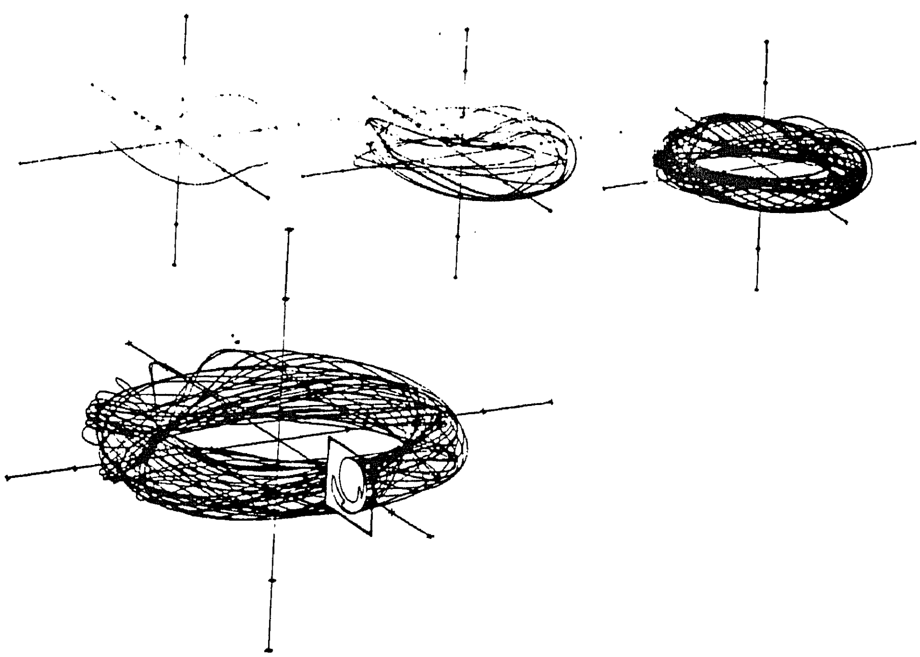


Figure 1.4: Lorenz Attractor (Chaos)

Although the point of reference at each stop along the loop tends to remain entirely unpredictable as to its location or inclusion, the general pattern will tend to follow a predictable path, and eventually reach a level of stability or entropy. A level of entropy is reached when the fewest interferences are found among the results of the choice process.

A contemporaneous model or freeze-frame representation of current information, at some arbitrary point along the loop, might further be seen as similar to the result of cutting any of the infinite choices of Poincare' sections.

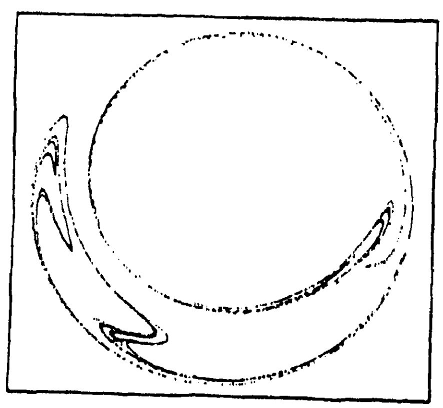


Figure 1.5: Poincare' Section through a Lorenz Attractor.

Each section represents only whatever small portion of the overall model that it might, but assured to be compatible with any other section of information.

This interactive method of meshing all of the control parameters into the same, singular model would provide a necessary consistency among all views of a model automatically. By reviewing the entire process to date at any given interval, the designer is assured of seeing a model that is coherent, feasible and complete.

CHAPTER 2
PROCESS OF DESIGN

Architecture is both a physical and a visual art, and its correct interpretation depends on accurate, understandable relationships among its component elements and properties. Words might be useful to help explain unseen or difficult conditions and methods, but cannot be presumed to replace effective presentation. The development of a design is an iterative process, meaning that from the beginning, and on through until the end, every decision made must be analyzed and checked against a series of design control parameters. At each point of reference or inquiry, all the decisions made must be traceable back through to the original design intent, as well as thought through toward the end product and its most finite details. Many of these finite detail decisions must wait for higher level decisions among the various controlling parameters. This implies that many of these necessary decisions must be put off, or admitted as default values, until an adequate level of completeness has been achieved for these decisions to be addressed.

Starting at an abstract or conceptual level, the design is controlled by variables that are determined by the choices of the client and design professional from among the most basic control parameters. These choices are necessarily loose and vague. There are few quantifiable limits on these choices beyond the constraints of a general aesthetic and programmatic criteria, the area available, zoning restrictions, generalized building codes and budget.

After each design review, the conceptual model is refined, and more definitive constraints are applied to the building's design. According to the type or class of building proposed, building codes provide distinct limits to; the type of construction allowed; size and area of spaces within the building; distances to exits; the overall height of the building; and distances to neighboring properties or buildings according to fire codes. As these distinct and quantifiable constraints are imposed on the buildings design, the designer must begin to make choices from among the variables allowed within these constraints.

2.1 Interference Checking

Decisions regarding spatial planning, choice of materials, and the style or pattern of details remain open to the ideals of the designer and client. As the design gets more refined, the limits imposed by the involved control parameters, of the building systems involved, can be applied. These control parameters have distinct and quantifiable restrictions, regarding the appropriate means and methods, by which the technologies can be applied. Structures; environmental control systems; lighting; acoustics; handicapped access; plumbing; and fire codes; each have properties and constraints regarding their use. All component elements of a building are analyzed against control parameters for appropriateness, practicality and design implications. If the individual designers do not check all component instance entries against the constraints and conditions of the conceptual model as the design progresses, interference conditions can be inadvertently created. a.) Interference conditions are created when entries are made based on decisions dependent on inaccurate, or out-of-date, reference models. b.) Interference conditions also exist when component entries are made dependent on an inappropriate control choice at a higher level. To achieve integration, the design may have to be reverted back to the level of acceptability. This can mean eliminating whole phases of prior effort in the design process.

In a wholly manual method of representation, this can mean either abandoning much of the work already completed, by spending tedious hours erasing or clearing entire sets of work, in order to get back to a level where the work can resume. In an integrated process the revisions can be inserted at an appropriate level, and any conflicting implications can be revised or refined, only to the degree necessary, to bring them in accordance with the initial design concept. If such conflicting levels of decisions can be flagged or marked as inconsistent; ambiguous; or as interference factors; the designer can more easily be alerted to the need to update the specific choices. At a regular checkpoint time, those individual decisions can be either cleared or modified, to the level required to make them fit within the parameters of the final design. (Zdonik, 1990)

This process remains iterative and redundant in any case, constantly moving up and down the scale of decision levels and parameter restrictions, until all (or as many as conceivable) of the decisions have been addressed, confirmed, and accepted. Once each component has been fit into the end product in a manner consistent with both the original design intent and the constraints of the various control parameters, the design process can be considered complete. By complete, the implication is that an accurate model of the final product has been created, a document model that can be recreated in actual, physical materials and systems, and assembled as a real, concrete, and utilizable construction.

CHAPTER 3

CONCEPTS OF MODELING

'Thirty spokes

share one hub.'

"Adapt the nothing therein to the purpose in hand, and you will have the use of the cart. Knead the clay in order to make a vessel. Adapt the nothing therein to the purpose in hand, and you will have the use of the vessel. Cut out doors and windows in order to make a room. Adapt the nothing therein to the purpose in hand, and you will have the use of the room. Thus what we gain is Something, yet it is by virtue of Nothing that this can be put to use."

Tao Te Ching

(Lao Tzu, 551-479 B.C.)

"The mechanistic world view of classical physics is useful for the description of the kind of physical phenomena we encounter in our everyday lives and thus appropriate for dealing with our daily environment, and it has also proved extremely successful as a basis for technology."

Tao of Physics

(Fritjof Capra, 1984)

Technology can be defined as: a designed system of means, methods and materials; intended to provide for an increased state of productivity, comfort, safety, or convenience; at the control of the user. This implies that whatever system we can design should allow the user to spend his time more effectively at conceptual and aesthetic levels of decision making. Whether active or passive, such systems should allow for simple, understandable control; at the hands or convenience of the user; regardless of the actual or implied complexity of the methods by which they function.

Simplexity: A term the author invented a number of years ago to describe the notion that no matter how much apparent complexity anything might reveal, it can invariably be reduced to a simple set of rules or definitions. Conversely, despite the apparent simplicity of many things, very complex patterns can be developed from just a few simple ideas. These connections can only be made, however, given a clarity of purpose and definition when the study is initiated.

In Architecture this is known as the "parti" or conceptual model. Without a strong concept, the implementation of the building's program through form and space cannot be realized in a coherent, usable, or aesthetic manner.

In order to convey the intent of a design concept, the architect must present his ideas through some kind of a model form for periodic design review. This model should sufficiently indicate the level of definition attained up to the time of presentation. The model should also provide enough information in basic form to allow for an understanding of what the more refined considerations might become.

Models are defined as abstractions or simulations of actual physical conditions. Design models are miniature representations of buildings that show the structure, form, and relationships of the component parts of a building. The design process follows a path from an abstract conceptual model, through more definitive levels of refinement as design review models, until it reaches a point where the building can actually be constructed. The model presented at any point for design review should reflect only the level of refinement attained during the process to date.

3.1 Comparison of Representation Techniques

3.1.1 Traditional Representations

Manual methods of design representation.

* Sketch: Loose, wide line drawings to show the basic plan and shape of the building.
* Accurate drawings: Use of straight edge, fine lines, notes to provide more specific information about design constraints.
* Graphic Illustrations: Interpretive drawings of key design issues, mostly used to sell a difficult design idea.
* Scale Models: Simple Massing, abstracted details and elements.

3.1.2 Computerized Representations

Simple programs that emulate traditional methods of representation.

* Raster drawing (CAD Graphics): drawing or painting with pixelized computer images.
* Vector drafting(CAD Drafting): geometric and trigonometric arrays of lines and curves.
* 3D CAD Modeling: Solid or wireframe massing of basic building elements as defined by vector analysis or Boolean configurations.

3.1.3 Computer Datafile Modeling

Building systems and design components are entered and identified at basic levels indicating parameters of control typically included as integral to design concept.

* Database Management and Object Oriented Modeling
  - -Each component element is entered as defined from within a "catalog" of allowable components as specified by control parameters and database control
  - -Each control parameter must still be analyzed independently through separate programs, although the computer greatly enhances the speed of review
  - -Composite is a virtual model which can be analyzed against any control parameter, modified with new information, combined with any other model set, viewed from any position, lit from any source, finished with any material, given any color or texture, walked thru in a sequential path with video simulation.

3.1.4 Integrated Component-based Computer Design Model (ICCDMS)

Control parameters are automatically analyzed, as each component is entered, to verify each component instance in the design. The resultant sum of the various control parameters, assures an integration of all of the properties and functions of the design model, through each of it's iterations.

3.2 Definition of Review Models

In order to define a review model using any of the above processes, the designer must be aware of both the limits of the presentation technique employed, and the special characteristics that make each technique valuable as a design tool. How many attributes are necessary to create an adequate, useable review model? How much analysis can be performed on the review model at each level of abstraction? Depending on which point in the design process the review presentation is made, it is appropriate to reflect only the relevant amount of information that can honestly and adequately be assessed from the results of the process to date.

At any stage of the design, there is a continuous process of interpreting graphic and semantic information. Industry standards of graphic conventions are used to convey consistent meaning to the representation of designs, design elements and systems. The systemic relationships of parts and functions are understandable only to the related tradesmen who know how to interpret the symbols used in their representation. Computers can be used to emulate the traditional representation methods and provide illustrations using similar conventions, but interpretation of the meanings of symbols, and their relationships, must still be performed by a human counterpart. Integration of all of these processes, mathematically and semantically, can be performed by using an ICCDMS to produce both a coherent single model of the design, and concurrent visual representation, at any point in the design process.

In the earliest stages of the design process, when only vague generalities have been determined, a rough sketch or quick massing model would suffice. By not offering too much information, the designer assures the client that the model is still flexible enough to respond to whatever changes might be called for.(Shoskes, 1990)

At more refined stages of the design, a degree of accuracy in the model representation is called for. The model should provide specific information, and visualizable imagery, depicting its most current component make-up. The information shown should provide each control parameter with the necessary "knowledge" to analyze the design components for verification within established constraints. Compliance with control parameters will allow more detailed levels of refinement. In manual drafting the designer must ensure that all of the various views of any given component, or space, within the overall design; must each provide a consistent, accurate and coherent representation of that same object or space. This relies on careful manipulation, and redundancy of documentation, to guarantee cross-referencing consistency. Sections, plans, elevations and illustrations must all agree. An ICCDMS would provide absolute consistency, among all views, automatically.

During the design process, it is ordinary to test conditions in the design model that depend on unknown parameters within the design concept. This may expedite the design process, by allowing the architect to push a concept to new limits, or explore possible alternative solutions. Before accepting any tested solution, interference conditions must be adequately analyzed for compatibility within control parameters. Solutions may test as either untenable or incongruous with the design, and must be either modified to allow inclusion, or precluded from the final design. Use of an ICCDMS provides a means to analyze the implications of basic design considerations, without the need to create separate documents for each analysis, presentation and review.

The final representation of the model should be regarded as the most critical tool of the construction process. As a document model, the final presentation must depict a correct and realizable system of coherent and concrete physical design components.These components should be acknowledged and integrated among all control parameters. The document model serves as the set of instructions necessary to construct the final design as conceived.

CHAPTER 4

ISSUES OF REPRESENTATION

By applying traditional design representation techniques, a designer working with drawings and/or scale models must necessarily create entirely different sets of information at each level of the design process to provide any required view of plan, elevation, space or site. These views are presented with two-dimensional or three-dimensional sketches or hard-line drawings. Scale models of the object, parts of the object, or the object within its context can also be crafted. (Although referred to only as scale models, the author implies many modeling forms or methods. Techniques include clay modeling, cardboard, foam-core, wooden or paper models, and more abstract materials. The reference to scale models should be understood to include any method, but that they are being deferred to provide a simpler argument.)

4.1 Manual Graphics

Drawings evolve from freehand sketches toward more finite limits of definition, until final construction documents are prepared. Each level of definition is typically begun on a fresh sheet of paper, overlayed on the last, tracing the portions that will continue, detailing the portions that have been more closely resolved. Some changes can be made to existing drawings by erasing prior sets of information and redrawing only those affected areas of the model. Any drawing page can also be made more informative by augmenting the semantics of the basic graphic representation. This can be achieved by adding notes, by drawing more accurate details or by providing larger scale drawings of conditions too finite to depict at the base scale. Separate sets of drawings are usually created to address each of the various control parameters. Much of the process through drawings of the design model is necessarily redundant, as each view must provide a sufficiently full account of the factors that apply to any portion of the construction.

4.2 Constructed Scale Models

Scale models typically begin with the simple massing of forms, indicating the general shape and configuration of masses, as they relate to each other and their general context. As the design progresses, the models become more specific and formal, indicating the different spaces as they are limited by floor areas and voids; wall areas and voids; and overhead limits imposed by structural configurations and roof enclosures. Any further depiction of details in a scale model is limited only by the designer's ability to sufficiently miniaturize the visually ascertainable characteristics of components, as they are applied to the composite formal model.

It is possible to recreate reasonable simulations of design components and systems well enough to produce a "working" scale model. The cost and time necessary to assemble such an intricate model are prohibitive in the average design process. The information provided by such a physical scale model remains as only a visual reference of the design concept. A scale model, however, does not provide direct, physically utilizable information, for analysis of any of the more quantifiable control parameters. Analysis of such parameters as structure, acoustics, HVAC, etc. must still be examined through separate, and often redundant, sets of information produced by each of the interested parties, either as drawings or engineering calculations.

Full scale mock-up models can be built to provide a simulation of an actual condition (only up to the point of real context on completion). Mock-up models are very useful for analysis of certain physical and visual constraints. Though useful to study relatively small portions of an overall design scheme, the expense of physically constructing such models prevents their use in all but highly budgeted projects. Furthermore, these models can only be made to represent small portions of the entire design, whereas creating an entire model would indicate actually constructing the proposed design.

4.3 Semantics and Syntax in Representation

Attributes and properties of elements within most manual representations tend to be defined as lists of words or graphic symbols. When presented to viewers who have no prior knowledge of the symbols or terms, or if words and symbols are incorrectly presented to otherwise knowledgeable viewers, these words and symbols are not meaningful.

For instance, the word "WOOD" printed on this paper has no inherent characteristics, except that in its current syntax as symbols of English print form, it requires the use of five straight marks of a stylus and three (or five) curved marks. To be meaningful syntactically, these marks must be in the proper sequence and in correct proportion to each other. At the most finite level, the beginnings and ends of each mark should be within a recognizable proportionate distance of each other. The resulting symbols (marksets) must maintain a sequential adjacency and spacing to even be regarded as a word. Each word maintains an adjacency to other words and symbols, each made up of similar marks of a stylus. The string of words must in turn be in an understandable order to serve any semantically meaningful purpose.

While the word "WOOD" is a representation of a type or set of real entities, it is only meaningful to viewers who have an interest in the word's implications and can relate to a specific semantic association with the word. Similarly, the symbol for a door, or the 2-D representation of a staircase might have no semantic association to a person not trained in drafting or reading of architectural drawings. Therefore understanding architectural representation is a matter of interpreting the syntax (the symbols), to derive semantics (i.e. meaning).

CHAPTER 5

DESIGN CONTROL PARAMETERS

5.1 Multi-Parameter Representation

The following multi-parameter analysis will serve to illustrate how various parties who may have an interest in the word "WOOD" as it applies to buildings and architecture. Each party requires a different type of knowledge-base in the model to serve their particular interests. While one party would be interested in only the structural characteristics of the material, another might be interested in representing only the acoustic properties of the material.

The various constraints effected by each of the interested parties must refer to consistently identified component instances or component-sets. Each party will review the constraints of their particular control parameter from either a single model with multiple inheritances; or refer to various subset models of the same object. Each parameter review model requires only the information, for any component instance, that pertains directly to the constraints of each particular control parameter.

The client may have an interest in wood which may extend to the vague knowledge that it goes into the walls and floors structurally somehow. When exposed, it looks nice if it is polished, and maybe it could be used for the floors or some paneling. The client is also the first to ask, "But how much will all of that cost?"

A builder would want to know how many pieces of each different size and type are required, where each piece is located and how it is installed. The builder is also interested in how much it will cost, what substitutions for any other type can be made, and how many man-hours it will take to put all of the pieces in place.

A structural engineer will want to confirm how strong each structural piece is, and how much load it will carry. The engineer will also check for what kind of deflection each piece will allow at normal or extreme stresses, and how much each piece weighs, in and of itself. The engineer might also want to analyze whether it could be more economically effective, or structurally sound, if it were replaced with another material, such as steel or concrete.

An acoustics engineer would want to know the density of the material and how well it absorbs sound, or its STC rating. He will also determine what kind of connection it makes with other elements and the size and locations of any holes in the material.

Heating, Ventilating and Air Conditioning (HVAC) specialists would need to understand what thermal value each piece provides, singly or in combination with other elements. They will also check whether individual pieces can be drilled, cut or moved, to allow for ductwork or piping and if pieces can added to allow for other components to be attached to it.

Fire inspectors will check for the materials combustibility, whether it requires special protection in construction or is allowed in the construction class. They will also check each piece, or set of pieces, for interference with travel for egress requirements.

Someone interested in lighting would check for areas of reflectance, translucence, color, texture and location of each material as an exposed surface. Adequacy of the structure would be checked, where required to carry heavy fixtures, and for locations to mount fixtures that might require that pieces be penetrated to carry wires or hide fixtures.

The client will also ask if it is protected from the elements and can get wet, and how it would need to be protected; whether sealed with another material, painted, or varnished. He will again inquire about the cost, and how often it will require maintenance.

The client, or more properly the buyer, is the final decision maker regarding all of the involved trades. He can either accept or reject any of their suggestions for alternative solutions; and either restrict, or give tacit approval to, each of their involvements in the development of the final built product. He will choose to spend his money according to his own priorities (as influenced by the efforts of the architect).

5.2 Interdependence of Control Parameters

Other types of parameter integration affect the design process as well. The design model must depict a multi-faceted representation of component instances and component groups. Updating any component in a model requires an update to each parameter, as an interdependent subset, of a single control model. The following is a sample of the effects of a typical client inquiry. Many control parameters can be involved in the consequences of a relatively simple change in plan geometry.

A client might be reviewing the plan late in the design process, and because of new circumstances ask if a room can be made about fourteen feet wider. The architect would have to respond that it will involve many revisions to the design model. Some of the revisions implied by such a seemingly simple change might include:

All relevant drawings would need to be revised, including all plans, elevations, sections, related plans above or below the effected area, and several of the construction details and specifications.

The structure will have to be increased, either through the use of deeper joists; closer spacing of joists; or different (stronger) types of materials. This also implies the need for larger footings and stronger supporting beams to carry the additional load, and perhaps a different type, or size, of bearing wall or footing.

The heating and air-conditioning capacities will need to be increased to account for the enlarged volume of the space.

The lighting requirements will also be increased in order to meet minimum standards for the space. More electrical outlets will also be required.

The revised space will have different acoustic properties and may require the use of more sound absorption materials, or special sound dampening construction.

More finish materials will also be necessitated by the larger areas of the space.

All of these considerations, of course, will mean higher costs and must be weighed carefully within the budget limitations of the building.

5.3 Limitations of Independent Representations

There are obvious limitations to traditional representation methods when such changes are requested. Each of the above described changes must be made manually. Each interested party must make similar changes. Incorrect or insufficient information must be erased or removed from the previous record model. Each party must rebuild or redraw all of the relevant and necessary views of their particular model, to adequately describe and analyze the revision. All of the control parameter analyses must be made manually, and in many "hurry-up" situations are often ignored, or overlooked, under the aegis of waiting until the next review: "We'll study that later".

Because of the slow, laborious nature of manual methods, there is a reluctance to go through all of the processes, each time any change is explored or analyzed for verification before inclusion. These methods are inadequate to fully refine, and define, a design to a level of complete integration and maximum potential.

5.4 Integrated Representations

The computer model of a component-based design system must be able to propagate any revisions made to the design control database model, to each of the separate control parameter subset models. By simply changing the definition of any component object instance, or its location or insertion point from any given view, the computer program should automatically update all of the relevant information. This update should apply to whatever view, or control parameter analysis, the designer wishes to examine.

If the limits or constraints on any part of the model are exceeded by the implications of any change, the system should either automatically upgrade the involved instances of component elements through default or ambiguous definitions. The architect could be signalled to make decisions regarding the definition of the components in question. These decisions can either be triggered for automatic insertion, or left flagged for later consideration. In either case, the program can be set up to require resolution of the decision, before any final output can be registered as an acceptable version update.

Through ICCDMS, any time a component element will be entered into the design model, each component instance should maintain an informational database about its inherent properties, characteristics, and constraint implications. The design model can be defined as the set of representations used to illustrate the goal of the architect about the intent of the building's final realization, during the process of design. This information will remain with each instance as inherent knowledge, throughout the design process, as if it were being used in real time and space. At any time during the design process any component instance should be identifiable by the architect, client or individual designer to more fully understand the design model. This will allow any element of the design to be revised, updated, modified, omitted, moved or added to the model; much the same as a builder would in a real building.

By working with a single control model database to track the progress of the design model during the design process, any control parameter should engage only transparent, or working versions, of the model during any work session. Revisions should be explored without effecting the control model until verified for insertion as a version update. Through interactive processing, this will allow any concerned party access to a complete model for analysis, or design modification input or updates, at any time during the design process. By bringing all of the control parameters into the process from the earliest stages of design, the opportunity to overlook or interfere with the other control parameters while exploring the application of the most effective solution or technology, should be considerably reduced.

5.5 Identifying Control Parameters on Components

Each instance of any component element, as it is considered for inclusion in the design model, will have to be defined to include the relevant constraints and variables that make it unique, yet still identifiable as a common entity. This is achieved by defining each component as a component "type" in the control model. The database of a control model is defined by the information regarding all instances of any component type and how it will exist in the building.

Control parameters regarding allowable variables of building components and design constraints are typically hierarchic in nature. The need for different levels of abstraction or detail, during the design process, can also be patterned in a hierarchic structure. The design control model is established by determining the type hierarchies, within the conceptual hierarchy, that will govern each building model. Any component instance can be identified, by its location and inclusion among the various hierarchies of each control parameter, within the single control model.

This provides a standard method of definition, and assignment of component constraints and attribute variables, to correctly assess a design by any analysis program that might be applied to the design model. These variables should be uniformly identifiable, especially if an ICCDMS is to be employed effectively.

Any particular component of the design can be revised to meet new criteria due to new control parameter constraints. The implications of any change to a component, or component set, will affect the full range of information entered as the design model. The more automatic the updating process can be made, the more powerful and effective the capabilities of the architect become to integrate all components, and verify a control model version update. By maintaining a single control model in a database management system that will recieve a complete update on each verification. All other control parameters would have access to the most current information, constraints and characteristics.

5.6 Multi-Level Parameters

Individual component entities within a model carry values that identify each instance of that component, as it relates to all of the control parameters, at many different levels of abstraction. Any building component will have properties and constraints associated with it. Constraints usually refer to the limitations of the range of values one can assign to the attributes of each component due to functional, aesthetic, eoconomic, and other similar considerations. For example, at the most basic level, a door has properties that define it as some type of movable panel that either prevents or allows passage, through from one space to another. Its physical properties can be defined as being of a basic material characteristic and simply labeled as wood, metal, glass, plastic, cloth or some combination of those materials. The basic dimensions, action and function may also be determined.

The door's function can be described in terms of its means of action, and its purpose in the design concept. The action can be defined by whether the door slides or is hinged. The relative direction of the action can also be described as either vertical or horizontal; and further as opening up or down, or from the right or left. The purpose of the door reflects the constraints of which it may be described in terms of the relative privacy or security the door provides, the amount of protection from the elements or as fire control, or simply as a means of shutting off a storage space from view.

As a component of a building design system, a door has both material and functional property characteristics. The width and number of the openings must meet minimum standards for fire egress, based on codes concerning the expected occupancy of the space, which in turn is based on the area of the space. The dimensions of the door may also be further determined by programmatic or aesthetic considerations. The action, location and number of doors must also be ordered to provide the optimal use of the space enclosed, as well as to preclude the interference of the doors in another space.

The actions of the doors must not cause an impediment to a means of egress. In addition to the direction of action of the door, and its resultant position in an open condition, the mechanism by which the door is latched and released has implications on the function of the door, especially in an emergency situation. If it is possible or likely that the door will be secured or locked in a closed position, from either side, the allowable type of mechanism used is determined by how easily the mechanism can be released. Other constraints are created as a result of a variety of design control parameters such as acoustics, lighting, energy efficiency, structural implications and fire safety considerations.

Each instance of a door has a quantifiable capacity, determined by its construction and density, to: resist the spread of fire from one space to another; limit the passage of sound between spaces; limit or allow the passage of air, and its ensuing heat and humidity, as a component of environmental systems control. The surface characteristics of each door affect the design of lighting systems for spaces. The relative translucence or opacity of the door through any portion of its surface; or the reflectance of the door, based on its surface texture and color, affect lighting conditions.

5.7 Component and ComponentSet Updates

If some property of the door is found to be requiring modification, at a point in the design process where many instances of the door have already been located in the design model, the consequences of changing that property must be considered both for each instance of the door individually, and for all instances collectively.

If 12 doors with a width dimension of 2'-8" have been installed as instances of the same doortype, and only 3 instances of that door need to be increased in width to 3'-0", each door in the model requiring this update must be individually deleted, updated and reinserted.

If all 12 instances of the door can be increased collectively as a set of doortypes, than the set may be updated by revising the width dimension, from the definition of that doortype, within the database. Such a change to the database definition of the doortype should be engaged only within the design model database, and not as a general change to the system program database, as it would incur the same change, on all instances of the same doortype, in any design model. Such a change may clearly not be welcome in other design models, without due consideration of each model.

If doors or other elements of a design have been included as part of an array, or in a relational array with combinations of other elements; an update to one type of element in the array will be reflected in other elements in that array. For example, consider a pair of doors as part of an entry component. Consisting of symmetrically matched columns, sidelights, and transom windows, the whole is limited by a structural dimension, limiting its overall width, which cannot be revised due to other parameters.

If the width of only the pair of doors needs to be increased, the other component parts must change. By shifting locations of the other components to allow for the increased width, or symmetrically changing individual width dimensions to allow for the change in door width, while not increasing the overall width.

5.8 Subset Model Version Control

Subset models are maintained independently to address each of the various control parameters during the design process. Each subset model must be accessible to all other subsets to assure compatibility with each other, as well as the design control model, at each subsequent version of refinement during the design process. Many parameters are assigned ambiguously during the early phases of the design. The same door described earlier need only be defined as an opening condition with egress capability until well after all of the walls, floors, windows and other components have been determined, located and verified. The actual doortype and finish of the door and component hardware need not be fully identified until near the end of the process, being carried in the design model as a minimally defined ambiguous component entity.

The information carried from the design model to the working model should be limited to that which is minimally necessary for any interaction that applies to the control parameter in current operation. The subset model's working file size should be limited, during each interaction access to the design model, to maximize the speed of integration.

For instance, the designer deciding on lighting systems for a given space, would require only the information about a door that would be needed to analyze the control parameters of lighting. The door is defined for lighting analysis only by its specific amount of glazed surface with any relative transparency, or the color and texture of the opaque surfaces of the door and the total area of both.

This limited interaction can be achieved by maintaining a single control model, consisting of several subset models. Each parameter subset model would be addressed and ordered by individual processors, for each of the control parameters. Any subset model would contain only the identifiers of each component, as it relates or applies to the constraints of the control parameter that is addressed. All information concerning other control parameters dependent on component details, would remain buried in passive or hidden layers that do not need to be directly accessed.

A designer working between several various control parameters, would require a method of switching among model subsets, as instantaneously as possible. Computers working with only one processor are limited by the extremely large, overall working file memory size. The designer must load and unload separate functional programs, and complete modelsets, at each change in operational command. By adapting the use of multiple processors, the computer can have separate functional programs active on each processor. This would allow the designer to switch directly to each model subset requested and begin working immediately.

CHAPTER 6

HIERARCHIES OF COMPONENTS AND CONSTRAINTS

Components and component sets of a building must be entered through a consistent and logical hierarchy. This hierarchy must be set up for all systems of analysis, and evaluation of buildings and their components, for compliance with control parameter requirements. By use of an ICCDMS, the information or attributes of the individual components must be entered following a hierarchical order of object type, function, and constraint identification. Every component element used in any building has characteristics and properties that fall within a pattern, which can be traced from the smallest piece of hardware, back through to its relationship with the building as a whole. This hierarchical system of object identification, serves for the analysis of fire and egress requirements; structure; HVAC; lighting; acoustics; handicapped accessibility; electrical; plumbing; etc.

To break down a building into the various objective relationships among its component elements, all elements are first typically characterized as having a primary physical bearing. Component elements are essentially vertical or horizontal as solids, with openings or voids as a means to link spaces thorough from one to another.

Next, in order to define spaces within a building, it is necessary to understand the physical limits of the enclosed area. Horizontal conditions (intersecting elements or voids) comprise the vertical limits to a space, and vertical conditions form the horizontal boundaries of the space. Most elements are not limited to a strictly horizontal or vertical bearing, but the primary and/or functional characteristic will assign the proper aspect.

Every component attribute definition within these orders, is assigned as a refinement to the primary attribute of the higher order under which it falls. These attributes define each component element as a <u>type of</u>; <u>part of</u>; <u>property of</u>; <u>method of</u>; <u>material</u>; or <u>function of</u> the control parameter or component object-type hierarchy to which it is assigned.

6.1 Object or Component Type Hierarchies

The following pages show a graphic chart to illustrate these relationships, using different line types to illustrate attribute characteristics, with each subset enlarged to allow for easier analysis. For a thorough method of defining and understanding a building across many control parameters within an ICCDMS, this hierarchical chart will serve as the basis for the necessary ordering of each of the building design's various control parameters. The proper order and process of object identification, during building design and definition, is critical to the Design System's ability to adequately analyze the characteristics of any of the building elements, and their relationship to the building as a whole.

In a typical component type hierarchy, the relationship between objects is a part relationship, where each lower level object is defined as a part or component of a higher level object. For example, a hinge is a part of a door, a door a part of a wall, a wall a part of a vertical enclosure, etc. A component type hierarchy provides a generic description of the object to be represented. Instances of the parts in the type hierarchy inherit their attributes from the generic description, and create an instance of the whole object represented. Therefore, a type-instance (also called a class-instance) relationship determines the characteristics of an instance of the object represented. The specialization of each component instance determines its unique variations from the generic type description.

Figure 6.4 is type-hierarchy developed to represent building components within a part-of relationship. Variations in line type in this figure indicates other relationships such as property-of, function, etc. (Figure 6.2). One must also be able to extract functional views of the main type hierarchy model (Figure 6.5). the functionof a component determines its location in the functional hierarcxhy and is related to the main design model through a component- function relationship.

Figure 6.1: Overall Hierarchic Orders

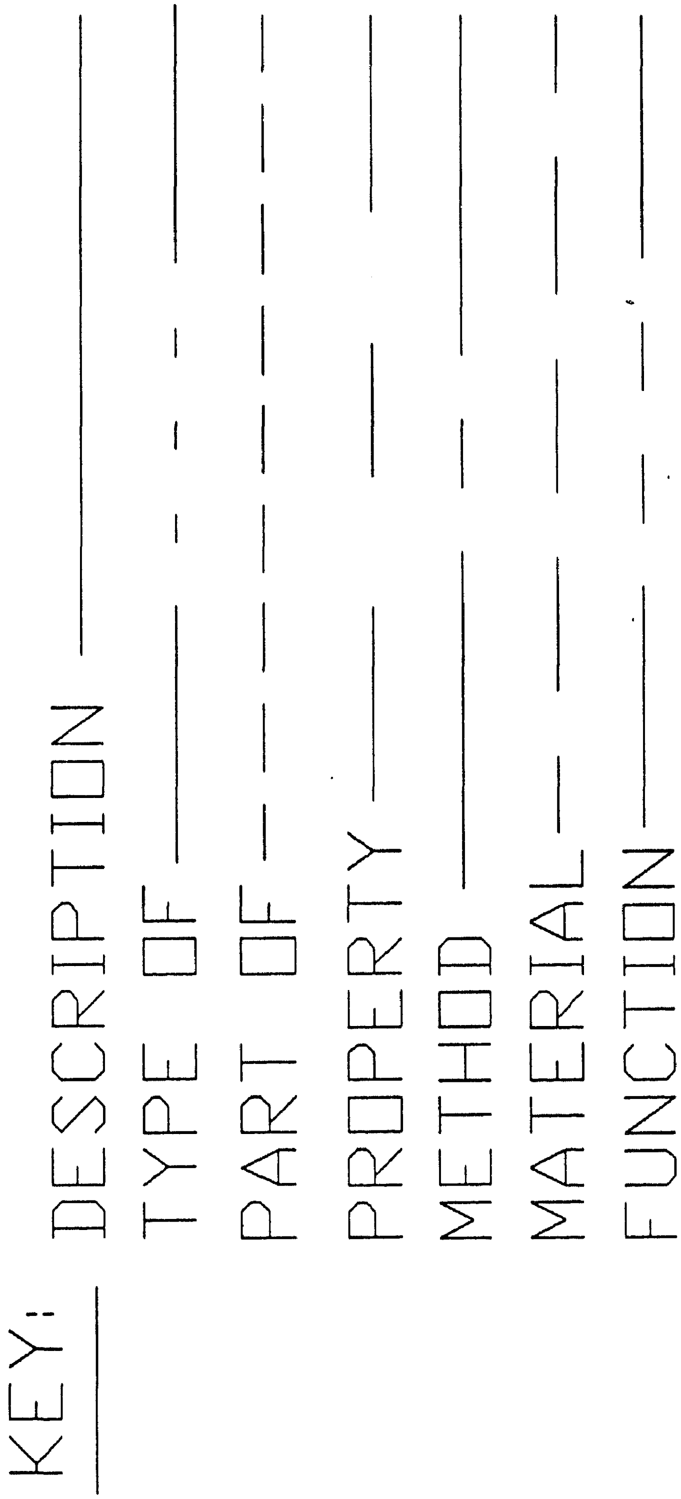


Figure 6.2: Key to Line Symbols

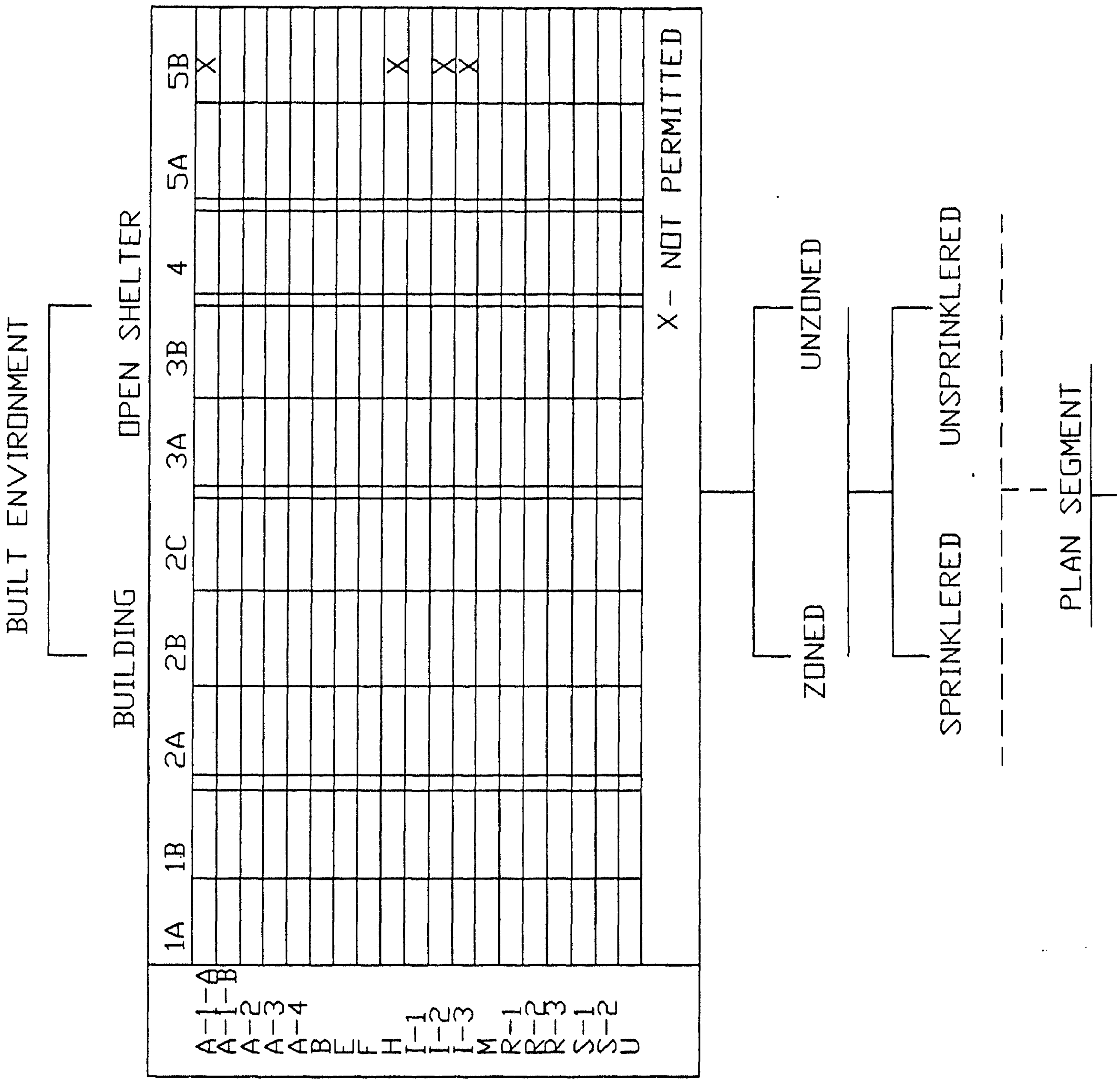


Figure 6.3: Initial Control Parameters

of Basic Conceptual Model

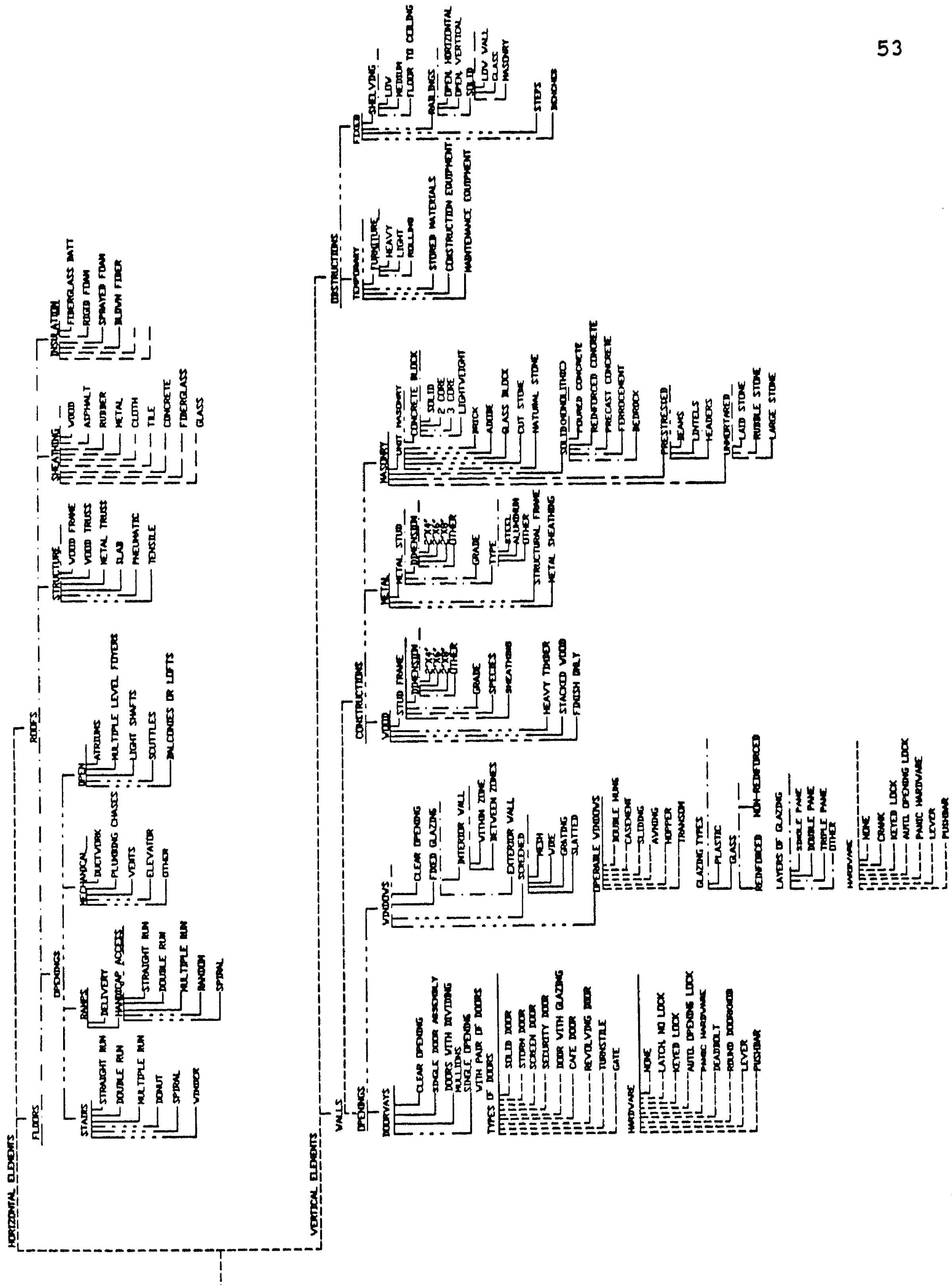


Figure 6.4: Component Object Relationships

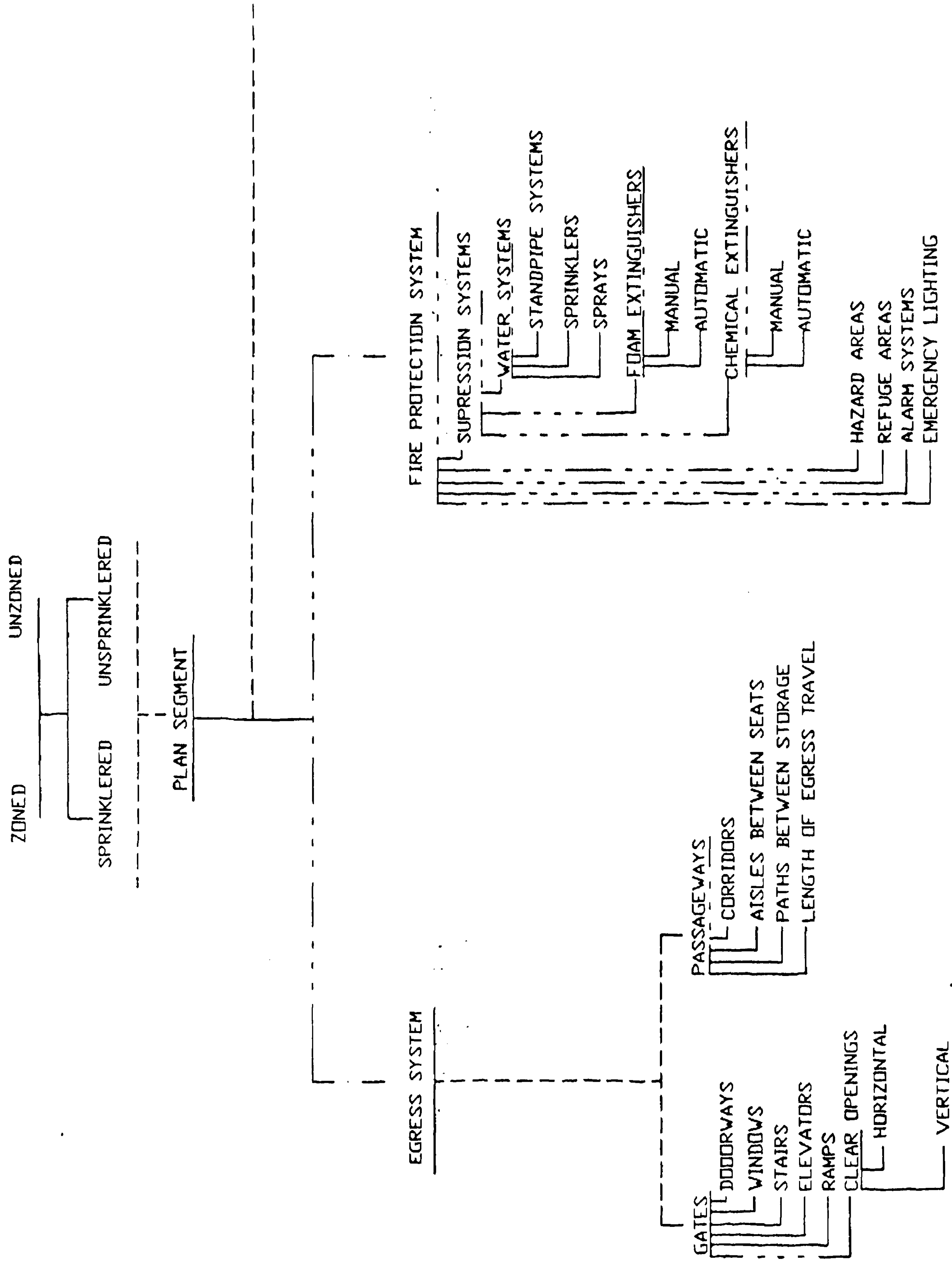


Figure 6.5: Egress and Fire Protection Constraints

6.1.1 Quantifiable Design Constraints

In order to translate the graphical nature of the above flow charts to a method of mathematical and semantic relationships that can be used by an architect as a basis for analysis, the following hierarchic orders occur. The semantic relationships of the graphic diagram describe that of the lower order constraint back through to the higher order constraints and basic conceptual model. The headings for each of the characteristics listed below differ from those of the graphic diagram, as they are based on an intuitive schema formed by professional experience, with each lower order decision or constraint following naturally from the higher order. The semantic relationships of components and constraints are based on a sample method introduced by Bonnie MacKeller of the NJIT Dept. of Computer and Information Science.

The following analysis of egress requirements is taken as far as the control parameter allows without going back to the primary identification, of which building class or occupancy type, is being analyzed. Unless followed through with a specific example of an instance of a building, finite determinations cannot be made, as the requirements change for each of the various construction classes and occupancy types. These requirements are defined in various sections of the B.O.C.A. Basic/ National Building Code (which applies only in this region) as well as other regional and local codes and the National Fire Prevention

Safety codes. As each code varies, the limits of these codes should be entered as default parameters and referred to within the program at the level of Built Environment as indicated by both the graphic and verbal analysis.

Outline of Building Systems for Fire Code Analysis

Built Environment

is a: controlled, designed environment

definition: construction of spaces for the use of human occupants

has components: solids and voids designed as a coherent, ordered system having adjacency to other built environments or open (non-controlled) spaces

can be part of: surrounding built environment or open space

properties: use group, construction class, area and volume, accessibility, zoning restrictions, economic considerations

constraints: applies only to assemblies of components set in place and determined by designed construction

methods:

determine: use or purpose of spaces
construction class
number of occupants

building height

building area (both total and by level)

building volume

****

Building

is a: built environment

definition: assembly of spaces determined by limits imposed by vertical and horizontal elements and openings, which are typically closed

has components: roof and contiguous walls or other closure all around

can be part of: surrounding built environment

adjacent to: other buildings or shelters, open spaces

properties: vertical and horizontal openings and solid elements, closures, fire suppression method, artificial lighting and ventilation systems,

constraints: different building types and classes of construction are determined based on type of occupancy, number of occupants, adjacency

methods:depending on occupancy type, choice of:

construction class is limited

height and area limitations are imposed

necessity of fire suppression system is determined

depending on conditions of above decisions:

allowable number of occupants is determined
required fire resistance ratings between zones is
determined
depending on number of occupants:
egress requirements are determined,including
size of exits
number of exits
length of allowable path of egress

Open Shelter
is a: built environment
definitions: structured space lacking either roof or
walls, or both
has components: limits to ingress/egress thru
perimeter,
barriers defining travel path(s)
can be part of: surrounding built environment
adjacent to: other open shelters, buildings, open
spaces
properties: vertical or horizontal elements and
openings
defining space and/or limiting access and egress
artificial lighting, natural ventilation
constraints: occupancy determines characteristics of
properties

methods:depending on number of occupants:

determine size of exits

determine number of exits

determine length exit access travel

determine width of aisles

determine distance between rows of seats

****

Plan Segment

is a: building

definition: any space, or group of spaces which can be isolated by temporary closure from open space

has components:

solids:

floors (horizontal limit below)

roofs and ceilings (horizontal limit overhead)

walls (vertical limit from floor to ceiling)

obstructions (vertical limits less than full height)

voids:

stair and ramp wells

mechanical chases

elevator shafts

multiple height spaces with openings at different levels

doorways

windows

hallways and other passageways

skylights

light and ventilation shafts

can be part of: any type of built environment

adjacent to: other plan segments, open space

properties: type of occupancy

number of occupants

means of egress

adjacency to other plan segments

construction type

materials

methods

structural integrity

furnishings or stored items

lighting systems

H.V.A.C. systems

finishes

fire suppression method

acoustic properties

plumbing

constraints:allowable size of space can be modified by the introduction of a fire suppression (sprinkler system)

methods: verify means of egress

verify minimum fire rated assemblies for walls, ceilings, structure, door and window assemblies verify locations of furnishings and/or stored materials

verify lighting systems for normal and emergency use

verify types and amount of finishes

verify fire suppression method

verify accessibility

verify acoustic requirements

verify plumbing systems

PURPOSE: Means Of Egress

is a: constraint

definition:easily determined method of escape from any one space thru another; to exit discharge; to outside, open space

has components: any starting point, exit access, exit passageway, exit discharge, exit

can be part of: set of means of egress

properties:

various lengths of travel distance

various degrees of fire separation between areas

limited number of exits

limited width and height of passageway

limited size of clear opening

constraints: travel distance includes paths around low obstructions (furniture, landscaping, handrails) path to exit must be easily and clearly understood or identified with signage if not within space

methods: based on criteria for building occupancy type and construction classification:

verify maximum exit travel distance from most remote space in plan segment

verify minimum number of exits required

verify minimum width and height of passageways

verify minimum size of clear openings at exit discharge

FUNCTION: Length of Exit Access Travel

is a: means of egress

definition: maximum distance to exit opening from any point in plan

has components: starting location (limited by the most remote point)

path of natural and unobstructed travel to exit discharge opening

exit discharge opening

can be part of: series of egress paths separated by areas of refuge

adjacent to: other areas requiring egress

areas of refuge

open space

properties: distance horizontally between and around
vertical obstructions along natural path to
exit discharge plus:
distance vertically from level of starting point
to level of horizontal discharge
constraints: length of exit access travel can be
increased thru the use of approved fire
suppression systems
methods: determine most remote location of plan
segment
verify compliance with exit access travel
distance
regulations for building type and occupancy
verify compliance of vertical circulation methods
with regulations
verify emergency lighting systems where required
verify alarm systems
verify posted exit travel diagram

FUNCTION: Minimum Number Of Exits
is a: Means of egress
definition: determined by occupant load and use group
has components: clear opening of minimum size thru
solid vertical element
operable closure with attached interior hardware
can be part of: series of egress paths to safe refuge

areas

adjacent to: safe refuge areas

open space

properties: see tables 808, 808.2, 808.3; BOCA 1990

A listing of the various control parameters and/or building functions which can be considered quantifiable constraints similar to those illustrated would include the following:

1. Structure, both method and integrity.
2. Heating, Ventilation and Air-Conditioning (HVAC).
3. Lighting, both daylighting and supplementary.
4. Acoustics, sound transmission and isolation.
5. Fire safety and code regulations.
6. Handicapped accessibility and viability.
7. Electrical Code and use requirements.
8. Plumbing, supply and waste requirements.
9. Zoning Regulations.
10. Building Code Regulations.
11. Costs, both construction and operating.
12. Rainwater control and environmental mitigation.

6.1.2 Design Control Parameters

In a typical design procedure, the architect proceeds by following a sequence of decision making analyses based on variable design control parameters. The basic conceptual model is generated concerning program requirements and the limits of the building are established.

The concept model is developed by ordering the following aesthetics and subjective parameters:

Owners preference
Designers preference
Style implications

and objective, quantifiable parameters and constraints:

Use requirements
Number of persons
Items to be processed or stored
Use group type (purpose)
Limits of available land or tenant area
Zoning limits
Deed Restrictions
Budget

Based on these constraints and limits, the building program is developed and modeled including, but not limited to:

Size of the building
- Height
- Area

Size of spaces within building
- Height
- Area

Structural need for clear span

Arrangement of spaces
- Program requirements
- Functional proximity
  - (i.e.-Executive--secretary--reception)
- Environmental considerations
  - Prevailing winds
  - View
  - Noise
    - On-site
    - Off-site
  - Odors
- Accessibility of building
  - Building to transportation
  - Between areas on site
  - Within zones of building
  - Within individual spaces
- Use Restrictions
  - Deed
  - Zoning
- Adjacency
  - To other buildings and areas
  - Among spaces and zones within building
    - Allowances for fire suppression use

Combinations of uses

Budget (redundancy intended)

After an elementary design model is approved, the designer makes more refined decisions about the definition of spaces and materials:

Desirability of materials

Availability of materials

Special market considerations

Donated materials

Promotional Display of specific materials or methods

Openings

Windows

number

size

arrangement

type

Doors

number

size

arrangement

type

Security

Doors

Windows

Alarms

- Special constraints
Subdivision of structured spaces
- Furniture arrangement
- Machine or storage layout

Interior Design
- Trim
- Patterns
- Finishes
- Lighting
- Acoustics

Budget

6.2 Design Constraints

6.2.1 Quantifiable Component Constraints

Building type-

Construction class

Use Group

Occupancy

Height and Area Limitations

Special Use and Occupancy Requirements

The above distinctions are established simultaneously and interactively in the early stages of design, based on programmatic and basic stylistic considerations. By the analysis of the program these distinctions guide the limits of any other choices that can be made. Through definition by code, all succeeding quantitative control parameter decisions are considered, prepared, characterized and initiated based on regulated limits. More qualitative considerations are left open to the designers discretion.

The following limitations and considerations are imposed, again both interactively and simultaneously. A formal hierarchical system is necessary to guide the process and ensure coverage of all the decisions that need to be made. Many of these decisions can go overlooked or inadequately analyzed if not performed as part of a formal review process. The following hierarchic system list has been prepared with a focus on fire code analysis, although the pattern is similar for other types of analysis.

- Means of egress
  - Horizontal circulation
    - passageways
    - corridors
    - refuge area (safe haven)
  - Vertical circulation
    - Stairs
    - Ramps
    - Elevators
    - Escalators
    - Fire Escapes
    - Ladders
    - Floor or Roof Openings
    - (Floor- Horizontal Walking or rolling surface)
    - (Roof or ceiling- Overhead limit to space)
- Enclosures
  - Walls (no passage)
  - Partitions (limited passage, no hurdle)
- Permanent Restrictions
  - Barricade (passage by stepping or climbing over)
  - Handrails
  - Curbs
  - Fences

- Retaining Walls
- Temporary Restrictions
    - Furnishings
    - Gates
    - Stored Materials
    - Furnishings
- Openings Thru enclosures
    - Doors and other solid, movable panels
        - Single action swing
        - Double action swing
        - Revolving
        - Sliding
    - Windows (Translucent or transparent wall panels)
        - Fixed
        - Operable
            - Ventilation only
            - Egress
                - Sliding
                    - Vertical (double hung)
                    - Horizontal (sliders)
                - Hinged
                    - Top hinge (awning)
                    - Bottom hinge (hopper)
                    - Side hinge (casement)
- Security or penetrability of opening
    - Locks and latches
        - Simple mechanical operation

Automatic operation

Keyed

Thickness and puncturability

Glass

Wood

Metal

Screen

Permeability of enclosure

Degree of fire and smoke separation

Solid (no openings)

Solid with openings

Doors

Windows

Ductwork

Mechanical Connections

Pipes

Continuous structural members

Electrical wire or conduits

Mechanical connections

Screen (primarily open to air passage)

Means of construction

Soil bearing capacity

Foundation

Basement or crawlspace

Slab

Footings

Continuous

- Pilings
- Floating Slab

Structural Frame

- Wood
- Steel
- Concrete

Membrane

- Interior
    - Plaster
    - Paneling
        - Wood
        - Metal
        - Tile
    - Gypsum
- Exterior
    - Siding
        - Wood
            - Sheathing
                - Particle Board
                - Plywood
            - Siding
                - Clapboard
                - Vertical Tongue & Groove
                - Shiplap
                - Shakes
                - Shingles

- Metal
  - Steel
  - Aluminum
- Glass
- Tile
- Masonry
  - Brick
  - Stucco
  - Cut Stone
  - Rough stone
  - Concrete
- Insulation
  - Batt
  - Rigid
    - Sprayed
      - foam
      - particle
- Vapor Barrier

Fire protection systems
- Lighting
- Alarms
- Extinguishing Systems
  - Automatic
    - Sprinklers
    - Foam
    - Chemical

Manual

Fire hose

Extinguishers

Isolability of space

Safe Refuge Areas

6.2.2 Constraints on Means of Egress

All spaces within a building need to checked for adjacency to refuge areas. This is a basic question of the location of the space in relation to any and all other spaces within a certain distance of egress travel. The accessibility to such adjacent areas is critical and determined by the following means of maximum and/or minimum dimensions. These constraint determinations vary according to the first level decisions made about Use group, Occupancy, Construction Classification and the use of Sprinklers.

Constraints with maximum dimensions include:

length of egress travel

height of steps or level change

area of space or zone

height of structure or number of floors

There are also minimum dimensional constraints regarding:

size of opening

fire penetration rate

distance to other spaces, buildings

height of spaces

area or amount natural ventilation

area or amount of lighting

There are minimum standards for physical or visual connection to refuge areas concerned with:

emergency lighting

clear width opening of corridor and exit doors

number of exits

audible alarms

Refuge areas are defined as:

Open space away from building

Interior space with two hour fire-separation,fresh air

courtyard leading to open space

separate fire zone within building

There are also allowable class of adjacent uses based on use group restrictions.

6.3.3 Dimensional Relations of Parts

For analysis of fire code; structural integrity; H.V.A.C.; sound; or lighting (regardless of aesthetic or other issues) most characteristics of component elements can be analyzed by examining the variables of distance regarding individual instances of components or the spacing between them. Since these component elements have inherent properties of density, structural characteristics and cost per unit, their variables can be determined by evaluating each element in terms of distances across mass, horizontal and vertical, and combinations of both. Spaces are also evaluated as quantitative distances but, of course, in terms defining the distances between masses. arious methods related to each of the control parameters are used to determine the relationships between instances of each component and the constraints on that componoent type. Distances can be broken down as various constructions of elements having thickness or depth, height, width and length. These distances are either measurements of elements, or measurements between elements.

Vertical distances are understood as they correspond and relate to measurements between limiting horizontal conditions, either as voids or solids, forming an edge to the verticality of the element in question.

Horizontal distances, therefore, are similarly understood as they are determined by the limits of vertical conditions, either solids or voids.

All elements can be characterized by these two variables of distances, and combinations of distances. The following chart tracks the variable limits of distances as they apply to egress codes and fire separation requirements. Distances up from the floor are quantified as they apply to egress requirements concerning the ability to make unimpeded passage over or around a component for safe egress. Component distances down from an overhead plane are considered for their ability to provide a smoke barrier between spaces or for creating any impedance to safe egress. Horizontal distances are considered against the same basic criteria.

Measured up from path surface:

From 0" to 5"

Curbs

Raised Walks

Bumper blocks

Storage racks or pallets

Door thresholds

From 0" to 8"

Steps

Stored materials

From 8" above 0", to 15"

Benches

Retaining walls

Stored materials

<u>From 15" above 0", to 30"</u>

Obstructions

Furnishings

Stored materials

<u>From 30" above 0", to 44"</u>

Handrails

Low walls

Counters

Furnishings

Stored materials

Maximum allowable sill height for egress windows

<u>From 44" above 0", to 72"</u>

Dividing walls

Partitions

Files

Stored materials

<u>Measured between horizontal limits</u>

<u>From 0" to 96"</u>

Typical residential wall height

<u>From 0" to any height</u>

any other contiguous wall height (Limit to Limit)

Maximum height above grade for fire equipment

<u>Measured down from overhead limit</u>

<u>From Upper limit down to 80"</u>

Minimum allowable egress passage head height

Door headers

Dropped girders or other structure

Passageway arches

Smoke or steam barriers

<u>Horizontal limits point to point</u>

<u>Maximums allowed by code restriction</u>

Egress travel distance

Floor areas for type of use

Distances between emergency lights, alarms

<u>Minimums allowed by code restriction</u>

Egress unit width

Light levels for various uses

Distances between sprinklers

All building components, component sets, and constraints are then entered into the design model as defined by horizontal and vertical limits to distance across mass or space. Floors are established by the limiting and/or supporting walls. More than one level or number of floors necessitates the use of vertical circulation elements. Stairs are a vertical circulation element. Walls are determined by the limits between floors and ceilings and/or other intersecting walls. Openings are extruded voids out of the solids of walls and/or floors. Windows are a type of vertical opening. Casements are a type of window.

Chapter 7 INTEGRATING COMPONENTS IN A DESIGN MODEL

7.1 Arrays of Components

7.1.1 Strict Dimensional Arrays

Some building component elements are limited to being entered in a geometrical pattern as standard size units. For example, 6 inch by 6 inch unit size ceramic tile flooring can be fit within a space by simply filling the area with X units by Y units, whether parallel to the space or across any angle. Any change in overall space dimension can be easily accommodated by adding more tile. The only other constraint that applies to adjusting a dimension of a space is to address whether the tiles should start: flush at one edge and continue across to a random dimension partial unit at the opposite edge; or to leave partial units of equal dimension at opposite edges, the overall pattern centered in the space. Changes in tile color or texture among the various units do not have any dimensional affect on the number or pattern of units, but do have a dimensional effect on the area of each subtype (color) of unit.

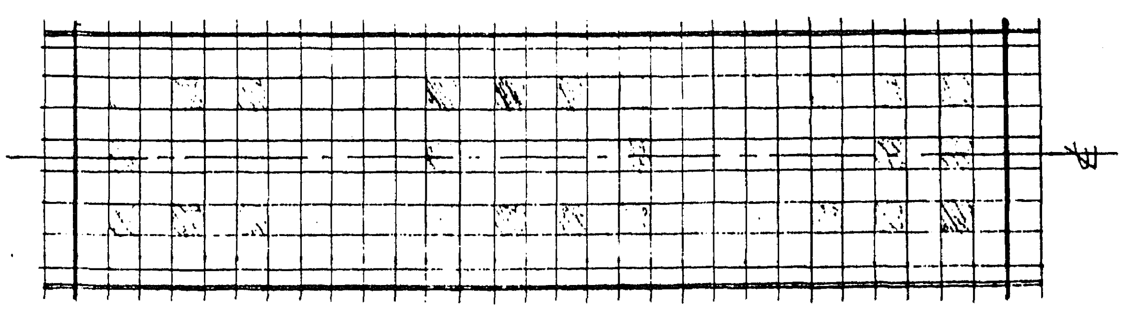


Figure 7.1: Array of Strictly Dimensioned Components

7.1.2 Relative Dimensional Arrays

Other component types are entered with locations that maintain a relative distance from, or between, other components. An example would be the placement of a set of light fixtures hung from the ceiling of a space.

The fixtures might be located in a grid pattern based on the division of the space into odd numbered sets in each direction:

any number of units (X or Y) = 2n + 1 ,

where n > 1 ;

with a limit ratio of distances (X' , Y') between walls and lights:

0.85 X' < Y' > 1.15 X' ;

and a maximum limit between units of:

X' < 8.0 ft.

Y' < 8.0 ft.

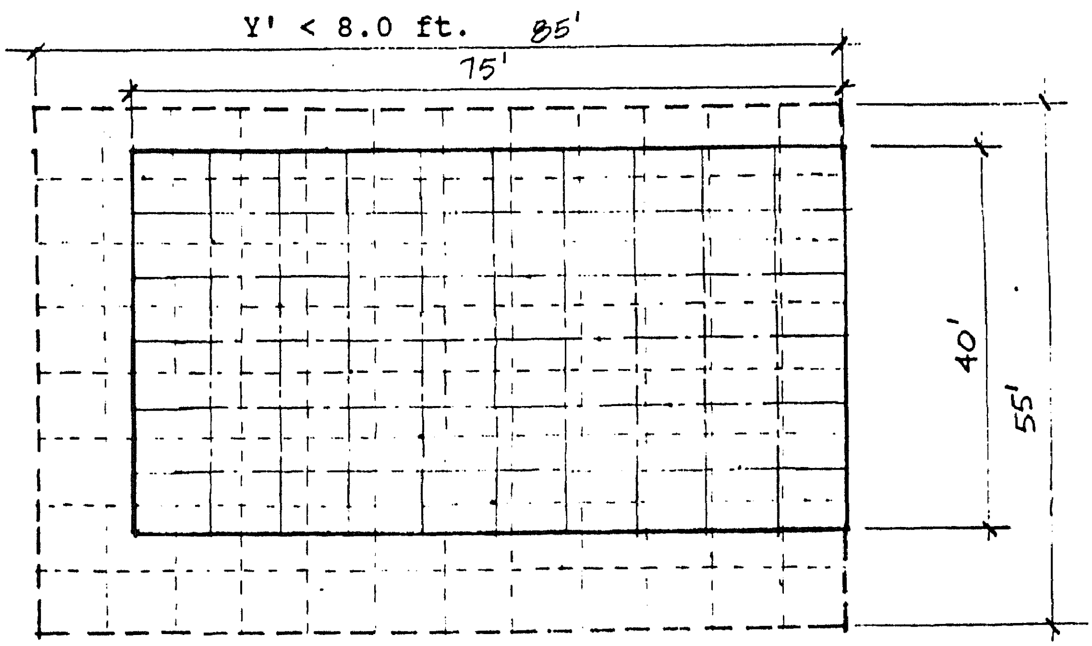


Figure 7.2: Array of Relatively Dimensioned Components

In a space of 40 ft. by 75 ft. as in fig. 7.2, this would result in a pattern of lights:

X = 40 ft./ 8 ft.

= 5.0

= 5 units (6 equal spaces @ 6.667 feet);

by Y = 75 ft./ 8 ft.

= 9.375

= 9 units (10 equal spaces @ 7.50 feet).

To check the ratio limit:

IF 7.50 / 6.667 = 1.125;

AND 1.125 < 1.15;

the spacing meets the design criteria and can be verified.

If the size of the space were revised to 55 feet by 85 feet, the same check would be run:

X = 55 ft./ 8 ft.

= 6.875

or X = 7 units (8 equal spaces @ 6.875 ft.)

by Y = 85 ft./ 8 ft.

= 10.625

or Y = 11 units (12 equal spaces @ 7.083 ft.)

And check the ratio limit:

IF 7.083 / 6.875 = 1.030;

AND 1.030 < 1.15;

this spacing also meets the criteria and can be verified.

To further illustrate the consequences on the constraints of other components by simple dimensional changes made to a space, the light fixtures might also maintain a constraint on the height of the lamp.

The lamp may have a minimum limit above the floor for egress clearance of:

$H > 80$ inches;

and a relative height below the bottom of exposed beams or ceiling coffers of:

$h < 3$ inches.

Following the example above, where the span of the space is increased from 40 ft. to 55 ft. and the control parameter constraint issued by structural analysis reveals that a new beam depth of an additional 7 inches is required, if maintaining the current structural type. This would indicate lowering the lamp by at least 4 inches, if the lamps were originally placed a full 3 inches below the beam, to as much as all 7 inches, if the lamps were originally hung flush with the beams.

If the fixture chosen has an adjustable length link to the ceiling, the change can be made easily, and can be allowed as a passive control. If however, the fixture chosen is a composite of fixed dimension subtype components, this would create an interference value, or trigger a disallowed function command and require an active control response. Either a different style lamp must be chosen, or a different structural system must be generated in order to meet the original criteria. If the light fixtures cannot be replaced for some reason, it may prove wiser to change the original criteria, than to initiate a full structural change from a higher order control parameter level.

The criteria for the light fixture choice and placement may not be a necessary control parameter decision until later in the design process. The response by the designer may remain as passive, using ambiguous limit ranges and allowing continuation on other design control parameters.

7.2 Ambiguous Constraints

All standard component elements entered should be selected from a list, graph or catalog of available types, with generic assembly or construction methods as a default value. However, specifications or variations to typical default values can be modified, as determined by the constraints implied to each component instance, as these constraints arise during the design process. By applying allowable limit ranges of component subtypes at the outset, specific component instances need not be defined concerning which type of element will be used as a design component during early phases of the design process. These ambiguous limits may have a trigger mechanism, to require a more finite selection of a subtype, after related threshold conditions among other parameters have been initiated. The ICCDMS system should account for decisions left unmade or passed over, by alerting the user with a system of flags or signals so that such decisions will ultimately be made.

The ICCDMS system should also account for what can be called imaginary limits to a space, such as changes in surface material, dropped or raised ceilings, implied room division by lighting patterns, adjacent variations in wall direction, corners within an L-shaped room, or the use of furniture as room division.

Many design decisions are based on abstract concepts such as symmetry, axial relationships, centralized organization, geometric patterns, proportional methods, and grid or matrix based planning. These concepts would need to be entered into the process at a preliminary stage of the design. As non-physical properties, such planning could exist on invisible layers as a strictly organizational overlay.

7.3 Managing Working Model Sizes

The necessary file sizes required to maintain such an extensive database for typical buildings are very large, as they are composed of so many different component instances. Limiting the file size during any operation sequence helps to increase the possible speed of the transaction. The design model in such an interactive system is composed of different subset models, each based on a particular control parameter. The subset models are accessed from, and addressed to, a single design control model. Each subset model would carry in its database only the portion of information about each component that it affects in the design model. The subset model is also structured along the order of its control parameter and carries all of the necessary relational constraints that any component must fit to satisfy verification within that parameter.

The total amount of information available to any representation of the design model relates also to the subsequent scale of the information presented within the format.

Views of the model from various scales are similarly detailed, only to the level of definition relative to that of viewing the actual building from an optically similar distance in real space.

CHAPTER 8

CONCLUSION

Traditional representation is a language of graphics, using symbols, line weights and line types, with words attached. It depends on the viewer of the drawings having a prior working knowledge of the conventions and implications of the techniques and semantic terms involved.

Computer aided drafting and/or design enables the architect to enter the design in a format that can be interpreted by any of a number of aftermarket software programs, as well as automatically produce graphic representations and documents. They allow for interpretation of the information involved and analysis by many of the various trades. This saves the designer valuable time and effort in ensuring that everyone involved is getting the same information and that whenever any change is made, the program typically enters the information in a manner that can automatically produce updated documents, without the time consuming effort of redrawing every view by hand. However, the computer process is still limited to a method of first entering the information, than analyzing it, than going back to refine or revise it. In many ways the computer is still the same as a manual development of a design.

An Integrated Component-based Computer Design Modeling System or ICCDMS, will provide the architect with the ability to pursue any course of design or process. The ICCDMS will require the use of multiple processors to manage and operate each of the control parameter subset models. Each parameter subset will analyze all component instance entries for verification and inclusion in the design control model. All version updates will be assured of consistency and integration by virtue of the continual and universal analysis of independent control parameters thru a single design control model. The final design document model will represent a wholly realizable building.

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